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Issued December 16, 1911.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS—BULLETIN No. 40.
LOGAN WALLER PAGE, DIRECTOR.

THE ROAD MATERIAL RESOURCES OF MINNESOTA.

DEPARTMENT OF AGRICULTURE
OCT. 1911

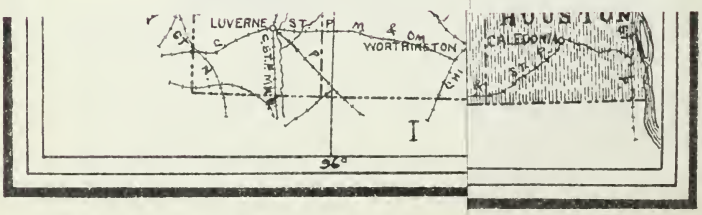
BY

GEORGE W. COOLEY,

SECRETARY AND ENGINEER, MINNESOTA STATE HIGHWAY COMMISSION,
SPECIAL AGENT, U. S. OFFICE OF PUBLIC ROADS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

97 Longitude West from Greenwich 96
CANADA
LAKE OF THE WOODS
KITTSON
ROSEAU
MARSHALL
Bottineau Island of Glacial Lake Agassiz
BELTRAMI
KOOCHICHING
PENNINGTON
RED LAKE FALLS
RED LAKE
LOWER RED LAKE
POLK
NORMAN
MAHNOMEN
BAGLEY
BEMIDJI
GRAND RAPIDS
HUBBARD
WALKER
CLAY
BECKER
PARK RAPIDS
CASS
DETROIT CITY
WADENA
AITKIN
CROW WING
BRAINERD
CARLTON
DULUTH
Cloquet
OTTER TAIL
FERGUS FALLS
Leaf Hills
TODD
MORRISON
MILLE LACS
GRANT
DOUGLAS
ALEXANDRIA
BENTON
STEARNS
ST. CLOUD
SHERBURNE
ISANTI
TRAVERSE
WILKIN
STEVENS
POPE
MORRIS
SAUK CENTER
BIG STONE
SWIFT
MEEKER
WRIGHT
HENNEPIN
ANOKA
CHIPPEWA
KANDIYOHI
LAC QUI PARLE
YELLOW MEDICINE
RENVILLE
McLEOD
CARVER
SCOTT
DAKOTA
SIBLEY
LINCOLN
LYON
REDWOOD
NICOLLET
LESUEUR
RICE
GOODHUE
WABASHA
BROWN
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FAIRMONT
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON
IOWA
LAKE SUPERIOR
Hunter's Island
INTERNATIONAL FALLS
Rainy Lake
Rainy River
COOK
GRAND MARAIS
Boundary Waters
Height of Land
Red River
Otter Tail River
Crow Wing River
Mississippi River
Minnesota River
St. Louis River
Pine River
Snake River
Kettle River
Root River
Zumbro River
Cannon River
Lake Traverse
Big Stone Lake
Lake Winnibigoshish
Leech Lake
Red Lake
Lake Pepin
Lake Mille Lacs
Lake Minnetonka
Lake Minnesota
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Lake Winnipeg
Lake Manitoba
Lake Winnipegosis
Lake of the Woods
Lake Traverse
Big Stone Lake
Lake Kabetogama
Lake Namakan
Lake Vermilion


LUVERNE
ST. P
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C.M.St.P.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Public Roads,
Washington, D. C., May 2, 1911.

Sir: I have the honor to transmit herewith the manuscript of a report, entitled "The Road Material Resources of Minnesota," by Mr. George W. Cooley, secretary and engineer of the Minnesota State Highway Commission. This Office has been considering the advisability of preparing and publishing similar data for all the States of the Union, but no definite steps toward this end have yet been taken. I recommend that this manuscript be published as Bulletin No. 40 of this office.

Respectfully,

Logan Waller Page,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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THE ROAD MATERIAL RESOURCES OF MINNESOTA.

INTRODUCTION.

GEOGRAPHY.

The northern boundary of the State of Minnesota was defined in the Webster-Ashburton treaty of Washington, August 9, 1842, as running from latitude 49° 23′ 53.28″ north and longitude 95° 8′ 56.7″ west from Greenwich, thence due south to the forty-ninth parallel of north latitude and west along that parallel. The southern boundary is the parallel of north latitude 43° 30′.

The eastern boundary was defined by Congress in the "enabling act" of Wisconsin, approved August 6, 1846, in substance as follows: From the waters of Lake Superior "to the mouth of the St. Louis River, thence up the main channel of said river to the first rapids in the same above the Indian village, according to Nicollet's map, thence due south to the main branch of the River St. Croix, thence down the main channel of said river to the Mississippi," and thence down the center of the main channel of that river to the northern boundary of the State of Iowa.

The western boundary is defined by the "enabling act" of Minnesota of 1857, as follows:

> Beginning at the point in the center of the main channel of the Red River of the North where the same crosses the northern boundary of the United States, thence up the main channel of said river to that of the Bois des Sioux River, thence up the main channel of said river to Lake Traverse, thence through the center of said lake to the southern extremity thereof, thence in a direct line to the head of Big Stone Lake, thence through its center to its outlet, and thence due south to the north line of the State of Iowa.

The area of the State according to the most carefully compiled estimates is given as 84,286.53 square miles, of which 5,637.53 square miles are water and 78,649 square miles land surface.

METEOROLOGY.

The mean annual temperature is given as 41°. The average rainfall for a series of years is about 27 inches, varying from 31 inches in the neighborhood of Lake Superior to a trifle over half that amount in the northwestern corner of the State. The main central portion is credited with about the average. The following table shows the

mean precipitation for the spring, summer, autumn, and winter months, taken from the Weather Bureau reports. To it is added a column showing the evaporation from a water surface as determined by the writer from a series of experiments on Lake Minnetonka, a lake covering 22 square miles, situated immediately west of Minneapolis.

Season.	Precipitation.	Evaporation.
	Inches.	*Inches.*
Spring	7.1	8.7
Summer	11.3	18.9
Autumn	6.7	9.2
Winter	2.2	4.2
Total	27.3	41.0

In ordinary winters frost penetrates the ground to a depth of from 2 to 4 feet where it is not protected by snow or vegetation, while where it is so protected, as in the marshy, timbered lands of the northern part, frost is frequently absent during the entire winter. The frost begins to disappear from March 15 to April 1, and that period is the most trying one for the road system of the State.

ADMINISTRATION OF ROADS.

The State is divided into 86 counties and about 1,800 townships. The counties exercise control of the county road and bridge fund and expend it by contract or day labor, or distribute it among the townships. Each township has a road and bridge fund of its own, expended by road overseers under the supervision of a town board. The average number of road overseers per average township of 36 square miles is 10. They are elected yearly, but are too frequently changed.

The amount of money yearly expended on all roads and bridges in the State approximates $4,000,000, of which about one-twentieth is expended under expert supervision.

ROCK FORMATIONS AND DRIFT DEPOSITS OF MINNESOTA.[1]

Granite, syenite, greenstone, gneiss, and schists, belonging to the Archean era, reach on the northern boundary of Minnesota from Gunflint and Saganaga Lakes west to the Lake of the Woods. Thence they extend south over a large part of St. Louis and Itasca Counties to the Vermillion and Mesabi Ranges. A narrow Archean belt continues from this great area southwesterly through Cass County. It is largely covered by the glacial drift and expands into a second large area of these rocks, reaching from Todd, Morrison, and Stearns Counties northeast to Carlton County and south to New Ulm. The extensive granite quarries near St. Cloud and Sauk Rapids are in this area.

[1]The author acknowledges his debt for the material in this section to an article by Mr. Warren Upham, secretary of the Minnesota Historical Society.

The same rocks also underlie a large district west of New Ulm, extending to the western boundary of the State, and are mainly covered by Cretaceous beds and glacial drift. In that part of the Minnesota River Valley, channeled about 150 feet below the general level of the country, the Archean granites and gneisses are seen in many and extensive outcrops. They have been quarried at Ortonville, near the mouth of Big Stone Lake.

In the northeastern part of Minnesota, adjoining Lake Superior, early Paleozoic rocks, comprising gabbro, slates, quartzites and conglomerates, occupy nearly all of Cook and Lake Counties, the southeastern part of St. Louis County, and the eastern part of Carlton County. Westward these rocks are thought to underlie the glacial and modified drift on a wide belt reaching to the lower part of Crow Wing River.

In southwestern Minnesota a great quartzite formation of the Taconic period has limited outcrops in Brown, Watonwan, Cottonwood, Pipestone, and Rock Counties, where it doubtless occupies large areas beneath the drift. From Pine County south to the Iowa line and reaching east into Wisconsin, there is a great series of upper Cambrian sandstones, limestones, and shales. Another and similar series of the lower Silurian age, chiefly limestones and shales, lies in the vicinity of St. Paul and Minneapolis and has a large development southward, from that point flanked on each side by Cambrian formations.

The latest of the Paleozoic strata in Minnesota are scanty Devonian limestones, shales, and sandstones, observed in Mower County and continuing into Iowa.

Sandstone of the Upper Cambrian series is extensively quarried at Hinckley and Sandstone, in Pine County; and limestone of the same period is obtained at Kasota and Mankato, in the Minnesota Valley. Quarries of smaller extent are also worked at many other places in both the Upper Cambrian and lower Silurian series.

Frequent outcrops of Cretaceous shales and sandstones, continuous from their great expanse on the western plains, occur in some parts of central and southern Minnesota; and in numerous other places deep wells, after passing through the thick covering of glacial drift, encounter these Cretaceous strata, which sometimes are found to reach to a thickness of several hundred feet. Cretaceous shales have also been discovered on the Little Fork of the Rainy River and on the high Mesabi iron range. The whole State west of a line drawn from the west end of Hunter's Island, on the Canadian boundary line, southward to Minneapolis, and thence southeastwardly through Rochester to the Iowa State line, is not, of course, spread over with the Cretaceous deposits. In fact, there are many places where the drift lies directly on the Silurian or earlier rocks, but throughout this part of the

State the Cretaceous deposits exist, at least in patches, and perhaps once existed continuously.

Nearly all of Minnesota is also overspread by the glacial drift; indeed, the only exception is a relatively narrow unglaciated area bordering the Mississippi River from Lake Pepin southward and extending into Wisconsin and Iowa. North of Lake Superior the drift on some tracts is thin and its average depth there probably does not exceed 50 feet. In four-fifths of the western part of the State it averages from 100 to 150 feet in thickness, almost everywhere concealing the bedrocks, which generally had been subaerially eroded in preglacial times to an approximately flat or only moderately hilly surface.

On certain belts the drift was left in hills and ridges which had accumulated, during the closing state of the glacial period, along the margin of the ice wherever it halted in its general retreat or temporarily readvanced. Upon the greater part of Minnesota the hills are formed of only this morainic drift, ranging in height commonly from 25 to 75 or 100 feet, but occasionally attaining a much greater altitude, as in the Leaf Hills, which rise from 100 to 350 feet above the moderately undulating country on each side.

Unstratified glacial drift, known as till or bowlder clay, which was laid down by the ice-sheet without modification by water transportation, assorting, and deposition in beds, forms the surface of probably two-thirds, or a larger part, of Minnesota. It consists of bowlders, gravel, sand, and clay, mingled indiscriminately together in a very hard and compact formation, which, therefore, is frequently called "hardpan." The bowlders of the till are usually so plentiful that they are sprinkled somewhat numerously on the surface.

The morain belts of knolly and hilly till have far more abundant bowlders than are found on its more extensive, comparatively smooth tracts. Wherever the vicissitudes of the wavering climate caused the border of the ice sheet to remain nearly stationary during several years, the outflow toward the melting, steep, frontal slope brought much drift, which had been contained in the lower part of the ice, heaping it finally in hills and ridges along the ice margin. Twelve of these marginal belts of drift knolls and hills have been traced in irregular looped courses across Minnesota and have been described and mapped in the reports of the State geological survey.

About a third part of the entire mantle of drift consists of the deposits known as modified drift, formed of water-worn and stratified gravel, sand and clay, or silt, which were washed away from the drift upon and beneath the retreating ice sheet by the streams, due to its melting and to accompanying rains. Hillocks and ridges of gravel and sand (known as kames and eskers), sand plateaus and plains, and the valley drift, which varies from very coarse gravel to very fine

clay, often eroded so that its remnants form terraces, are the principal phases of the modified drift. In being derived directly from the ice sheet, these deposits had the same origin as the glacial drift forming the common till and the greater part of the marginal moraines; but they were modified, for large bowlders are not included, while the gravel and finer portions were brought by water, further pulverized or rounded, and assorted in layers.

The action of glacial forces has so uncovered rock formations and caused the deposit of other material at such points throughout the State as to justify the statement, so often made in Minnesota road conventions, that few States in the Union have been more highly favored than Minnesota in the distribution of material suitable for the construction of highways.

QUARRIES AND CRUSHING PLANTS.

The following is a list of the owners' reports of quarries and crushing plants in Minnesota:

County	Le Sueur.
Location	Kasota.
Owner	Breen Stone Co.
Kind of stone	Dolomitic limestone.
Quantity	Ample for all purposes.
Capacity of crushing plant	100 cubic yards per day.
Use	Buildings, riprap, municipal work.
Cost of crushed stone	75 cents per cubic yard of 2,500 pounds, f. o. b. at quarry.
Railroad facilities	Ample.

County	Dodge.
Location	Secs. 13 and 14, T. 107, R. 17, near Dodge Center.
Owner	Wasioja Stone Co.
Kind of stone	Limestone.
Quantity	Unlimited.
Use	Locally reported as good road material. Has been used at several places for macadam.
Railroad facilities	Ample.

County	Hennepin.
Location	Minneapolis.
Owner	Minneapolis Stone Co.
Kind of stone	Blue limestone.
Quantity	Unlimited.
Capacity of crushing plant	600 cubic yards per day.
Use	Extensively used for foundations, walls, riprap, roads.
Cost of crushed stone	At quarry, $1 f. o b. cars.
Railroad facilities	Ample.

County	Dodge.
Location	Sec. 14, T. 107, R. 16, near Mantorville.
Owner	W. A. Sparrow.
Kind of stone	Limestone.

Quantity..... Unlimited.
Use..... Valuable for foundations, walls, riprap, and roads.
Railroad facilities..... 1½ miles from railroad.
Quarry not yet opened.

County..... Blue Earth.
Location..... Mankato.
Owner..... Fowler & Pay.
Kind of stone..... Limestone.
Quantity..... 20 acres, 30 feet thick.
Capacity of crushing plant..... 100 tons daily.
Use..... Building purposes, riprap, roads. Extensively used in the vicinity and different portions of the State.
Cost of crushed stone..... At quarry from 75 cents to $1 per cubic yard of 2,400 pounds.
Railroad facilities..... Ample.

County..... Goodhue.
Location..... T. 109, R. 16, near Pine Island.
Owner..... C. K. Hamlin.
Kind of stone..... Trenton limestone.
Quantity..... Unlimited.
Use..... Available for all purposes, but at present used only for roads.
Railroad facilities..... 2 railroads, each 1 mile distant.

County..... Dodge.
Location..... Sec. 21, T. 107, R. 16, near Mantorville.
Owner..... Mantorville Stone Co.
Kind of stone..... Limestone.
Quantity..... Unlimited.
Use..... Building and road work.
Railroad facilities..... Ample.

County..... Fillmore.
Location..... Sec. 9, T. 103, R. 13, near Spring Valley.
Owner..... W. H. Carey.
Kind of stone..... Limestone.
Quantity..... Unlimited.
Use..... Available for all purposes. Some crushed at Spring Valley for roads.
Railroad facilities..... 3 miles from railroad.

County..... Washington.
Location..... Stillwater.
Owner..... C. Carli estate.
Kind of stone..... Dolomitic limestone.
Quantity..... Unlimited.
Use..... Building and road work.

County..... Blue Earth.
Location..... Mankato.
Owner..... A. Jefferson & Son.
Kind of stone..... Limestone.
Quantity..... Unlimited.
Use..... Buildings, municipal work, and roads.
Railroad facilities..... Ample.

County..... Ramsey.
Location..... St. Paul.
Owner..... C. Bielenberg.
Kind of stone..... Blue limestone.
Quantity..... About 5 acres.
Use..... Buildings, foundations, and roads.
Railroad facilities..... Ample.

County..... Hennepin.
Location..... Minneapolis.
Owner..... Cook Stone Co.
Kind of stone..... Blue limestone.
Quantity..... About 3 acres.
Use..... Foundations, buildings, and roads.

County..... Winona.
Location..... T. 106, R. 9, near Lewiston.
Owner..... Hossfeld & Simon.
Kind of stone..... Gray limestone.
Quantity..... Ample for all purposes.
Use..... Buildings and roads.
Railroad facilities..... Convenient, but not developed.

County..... Blue Earth.
Location..... Mankato.
Owner..... T. R. Coughlan Co.
Kind of stone..... Limestone.
Quantity..... 30 acres.
Use..... All purposes. Extensively used for macadam and concrete.
Cost of crushed stone at quarry.... From 80 cents to $1 per cubic yard.
Railroad facilities..... Ample.

County..... Blue Earth.
Location..... Mankato.
Owner..... The Widell Co.
Kind of stone..... Dolomitic limestone.
Quantity..... 100 acres, 30 feet deep.
Use..... General building purposes and roads.
Capacity of crushing plant..... 300 cubic yards daily.
Cost of crushed stone..... From 72 to 80 cents per cubic yard of 2,400 pounds.
Railroad facilities..... Ample.

County..... Hennepin.
Location..... Minneapolis.
Owner..... Blue Limestone Co.
Kind of stone..... Blue limestone.
Quantity..... 8 years' run.
Use..... General purposes and roads.
Capacity of crushing plant..... 300 cubic yards daily.
Cost of crushed stone at quarry... $1.10 per cubic yard f. o. b. cars.
Railroad facilities..... Ample.

County..... Winona.
Location..... Minnesota City.
Owner..... Biesang Stone Co.
Kind of stone..... Dolomitic limestone.

Quantity..... Good for many years.
Use..... Buildings, city streets, and roads.
Capacity of crushing plant..... 250 cubic yards daily.
Cost of crushed stone at quarry... $1 per cubic yard of 2,500 pounds.
Railroad facilities..... Ample.

County..... Le Sueur.
Location..... Kasota.
Owner..... Babcock & Wilcox.
Kind of stone..... Limestone.
Quantity..... Ample.
Use..... Buildings and roads. Has been used on road work and reported satisfactory.
Capacity of crushing plant..... 100 cubic yards daily.
Cost of crushed stone at quarry... 3 cents per 100 pounds.
Railroad facilities..... Ample.

County..... Dodge.
Location..... Wasioja.
Owner..... W. E. Osborn.
Kind of stone..... Limestone.
Quantity..... Unlimited.
Use..... General purposes and roads.
Railroad facilities..... Railroad distant one-third mile.

County..... Blue Earth.
Location..... Mankato.
Owner..... M. C. Johnson.
Kind of stone..... Limestone.
Quantity..... Ample.
Use..... General purposes and roads.
Railroad facilities..... Ample.

County..... Blue Earth.
Locality..... Mankato.
Owner..... Alex Bashaw.
Kind of stone..... Limestone.
Quantity..... 2 acres.
Use..... Macadam and concrete work, also general municipal purposes.
Cost at quarry for crushed stone.. $1 per cubic yard.
Cost at quarry for riprap..... 35 cents per cubic yard.
Railroad facilities..... Ample.

County..... Washington.
Location..... 6 miles north of Hastings.
Owner..... W. P. Truax.
Kind of stone..... Limestone and sandstone.
Quantity..... Estimated 100,000 cubic yards.
Use..... General purposes. Quarry was opened by the Government for building dams and for riprap.
Railroad facilities..... Ample, but undeveloped.

County..... Mower.
Location..... Le Roy, T. 101, R. 14.
Owner..... J. L. Armstrong.
Kind of stone..... Limestone and sandstone.

Quantity..... Estimated 500,000 cubic yards.
Use..... Buildings and roads.
Railroad facilities..... Ample.

County..... Pine.
Location..... Sandstone City.
Owner..... Kettle River Quarries Co.
Kind of stone..... Sandstone.
Quantity..... Inexhaustible.
Use..... Bridges, buildings, paving, macadam, concrete, etc.
Capacity of crushing plant..... 300 cubic yards daily.
Cost of crushed stone at quarry... 90 cents per cubic yard.
Railroad facilities..... Ample.

County..... Pine.
Location..... Sec. 34, T. 43, R. 20, Banning.
Owner..... Barber Asphalt Paving Co.
Kind of stone..... Sandstone.
Quantity..... Inexhaustible.
Use..... Bridges, buildings, paving, macadam, concrete, etc.
Capacity of crushing plant..... 50 cubic yards daily.
Cost of crushed stone at quarry... $1 per cubic yard of 2,200 pounds.
Railroad facilities..... Ample.

County..... Benton.
Location..... Sauk Rapids.
Owner..... Misho Granite Co.
Kind of stone..... Granite.
Quantity ..... Unlimited.
Use..... All purposes; among others, for macadam roads in the vicinity.
Railroad facilities..... Railroad one-third mile distant.

County..... Stearns.
Location..... St. Cloud.
Owner..... J. G. Hilder.
Kind of stone..... Gray and red granite.
Quantity..... 40 acres, depth unknown.
Use..... All purposes; among others, for macadam roads in the vicinity.
Railroad facilities..... Ample.

County..... Stearns.
Location..... T. 123, R. 29, near Rockville.
Owner..... Clark & McCormack.
Kind..... Gray granite.
Use..... Buildings, road, and bridge work.
Railroad facilities..... Great Northern Railway.

County..... Morrison.
Location..... Sec. 24, T. 41, R. 31, 1 mile north of Gravelville.
Owner..... Davidson Granite Co.
Kind of stone..... Granite.
Quantity..... Not reported; presumably ample.
Use..... All purposes. Quarry not in operation at time of receiving report.
Railroad facilities..... 5 miles from railroad.

County..... Redwood.
Location..... North Redwood.
Owner..... Thomas Hoskin.
Kind of stone..... Granite.
Quantity..... 20 acres.
Use..... All purposes.
Railroad facilities..... Ample.

County..... Kanabec.
Location..... Sec. 6, T. 41, R. 23, about 10 miles north of Mora.
Owner..... Warman Creek Granite Co.
Kind of stone..... Gray granite.
Quantity..... Inexhaustible.
Use..... All purposes.
Railroad facilities..... Not developed.

County..... Pipestone.
Location..... Sec. 6, T. 104, R. 46, near Jasper.
Owner..... E. W. Davies.
Kind of stone..... Quartzite.
Quantity..... Unlimited.
Use..... Buildings, road purposes, bridges, and for concrete work and paving.
Crushing strength..... 23,000 pounds per square inch.
Cost of crushed stone..... Estimated $1 per cubic yard.
Railroad facilities..... Ample.

County..... Rock.
Location..... Sec. 27, T. 103, R. 45, near Luverne.
Owner..... R. B. Hinkley.
Kind of stone..... Red jasper (quartzite).
Quantity..... 680 acres.
Use..... General purposes, paving, macadam, etc.
Railroad facilities..... Favorable, but not developed.

County..... Nicollet.
Location..... Sec. 35, T. 110, R. 30, near New Ulm.
Owner..... New Ulm Stone Co.
Kind of stone..... Quartzite.
Quantity..... Inexhaustible.
Use..... All general purposes. A large quantity has been used for street macadam in St. Paul, Minneapolis, and other cities.
Capacity of crushing plant..... 200 yards daily.
Cost of crushed stone at quarry.... $1.20 per cubic yard of 2,600 pounds.
Railroad facilities..... Ample.

County..... Renville.
Location..... Near Morton.
Owner..... John Anderson.
Kind of stone..... Granite.
Quantity..... Unlimited.
Use..... Bridges, culverts, and buildings.
Railroad facilities..... Ample.

County..... Aitkin.
Location..... Sec. 14, T. 47, R. 25, near Kimberly.
Owner..... H. B. Ayers.
Kind..... Quartzite.
Quantity..... Unknown, but ample.
Use..... Local building purposes and roads.
Railroad facilities..... Convenient, but undeveloped.

County..... Chisago.
Location..... Taylors Falls.
Owner..... Northwestern Crushed Rock Co.
Kind of stone..... Trap.
Quantity..... Unlimited.
Use..... Surfacing and concrete.
Railroad facilities..... Ample, but not yet established.

County..... Big Stone.
Location..... Ortonville.
Owner..... Consolidated Granite Co.
Kind of stone..... Granite.
Quantity..... Unlimited.
Use..... Buildings, roads, monuments, and railroad work.
Railroad facilities..... Ample.

LOCATION OF ROCK DEPOSITS IN MINNESOTA.

LIMESTONES, MISSISSIPPI VALLEY.

The most extensive deposits of road-making material in the State are the limestones, which are found in situ along the Mississippi River from the southern boundary of the State to the Falls of St. Anthony and in the ravines reaching inland at frequent intervals. They also appear at Stillwater, on the St. Croix River, about 20 miles above its mouth, and at several other points throughout the eastern portion of the State.

This stone, when carefully selected from the hardest strata, has been used more extensively than any other for road building and when properly placed has great value. Its cementing value is especially high, and this quality makes it valuable for use on light-traffic roads, as has been frequently demonstrated on roads contiguous to the source of supply. It has, however, little value as a wearing surface and must be plentifully covered with gravel or harder stone as a protection against disintegration and wear. It forms the base or lower layer of the macadam on University Avenue and other streets in St. Paul and of Lyndale and Hennepin Avenues in Minneapolis, as well as on a number of village streets and county roads in the southeastern portions of the State. The writer does not approve of the practice of placing this stone in one layer of from 8 to 10 inches, as is frequently done, but recommends the following as conducive to better results: First, there should be a layer of 4 inches on a suitable, prepared foundation, with the addition of from $1\frac{1}{2}$ to 2 inches

of clean gravel, spread uniformly over the surface. This gravel binder should then be thoroughly washed into the first course and the whole well compacted by rolling. The voids in stone from 2 to $2\frac{1}{2}$ inches in size are about 45 per cent when laid loose, but this percentage will be reduced considerably by rolling, and the entire mass can be made, with a gravel filling, into a firm, compact, and unyielding base. The second course of somewhat smaller broken stone should be treated with gravel in the same manner, and a layer of at least 2 inches or more of gravel or trap rock should be spread over the top as a wearing surface. Some limestone macadam roads have been built in Hennepin County consisting of but one layer of 4 inches of stone of inferior quality with from 3 to 4 inches of gravel on top, and after six years' wear they appear to be in good condition.

Roads of the same material without the additional gravel have been built in the counties lying along the Mississippi River and have generally given satisfaction where some attention has been given to repairs. This satisfaction, however, comes rather from the improvement of the road in comparison with its previous condition than from its own inherent excellence.

Ramsey County has the greatest mileage of limestone macadam roads in the State and is still building them, using material from the local quarries in Minneapolis and St. Paul. These roads are from 12 to 16 feet in width and from 6 to 8 inches thick, and the average cost, not including grading, culverts, and bridges, is about 55 cents per square yard. The cost of crushed stone at the quarries is from $1 to $1.10 per cubic yard of 2,500 pounds loaded on the cars.

Crushing plants are established at many different points along the Mississippi River between the Falls of St. Anthony and the southern boundary of the State, and material for macadam can be furnished at from 80 cents to $1 per cubic yard on cars of the Chicago, Milwaukee & St. Paul Railway, which parallels the river the entire distance at the foot of the bluffs. Gravel of superior quality is also plentiful, and with a dozen lines of railroad leading westward ample facilities are provided for the future construction of an excellent system of roads in the extreme southeastern portion of the State.

LIMESTONES AND SANDSTONES, MINNESOTA VALLEY.

Of the same general character, though varying somewhat in value with regard to hardness and road-building qualities, are the limestones and sandstones of the Minnesota Valley, which are found in abundance along the Minnesota River from its confluence with the Mississippi River at Fort Snelling to the vicinity of Mankato. Occasional outcroppings appear, with numerous erratic bowlders, and in places the surface of the valley is strewn with stone reduced in size

FIG. 1.—GRANITE OUTCROPPINGS FROM 50 TO 75 FEET HIGH, MORTON, MINN.

FIG. 2.—QUARTZITE QUARRY, NEAR NEW ULM, MINN.

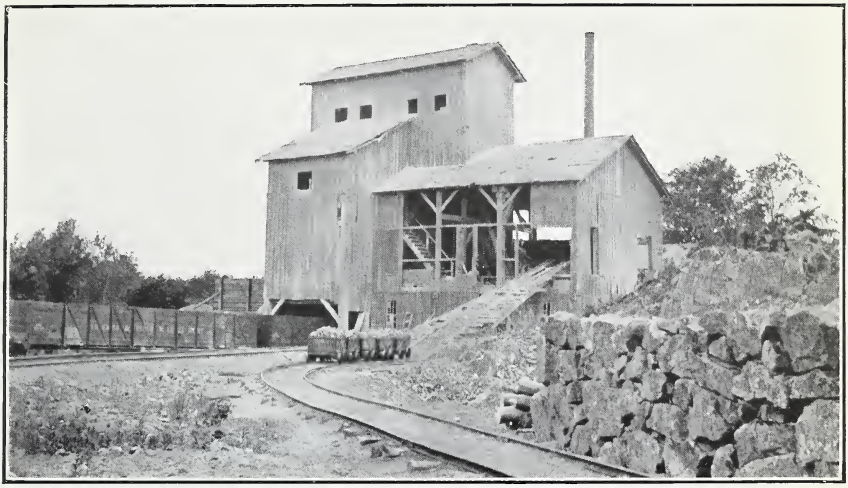

FIG. 1.—CRUSHING PLANT AT QUARTZITE QUARRY, NEW ULM, MINN.

FIG. 2.—GRANITE OUTCROP, GRANITE FALLS, MINN.

almost to that required for road purposes. This surface débris can be easily and cheaply collected, and the larger pieces can be broken with knapping hammers after delivery on the road. This material has been used to some extent just as taken from the fields, and where carefully laid and properly broken and compacted it gives fairly good results. In its use, however, too little attention has been paid to the value of a moderate uniformity in size, and it has often been dumped indiscriminately on the worst portions of the roads with the aim to improve, but with the general result of defeating, such a purpose. Gravel is also available in the near vicinity in ample quantities, and thus contributes to a combination of great value in the aid of easier transportation.

GRANITES AND QUARTZITES, MINNESOTA VALLEY.

Beyond New Ulm, advancing up the Minnesota River, the granites and quartzites appear in situ and as erratics in inexhaustible quantities and are conveniently located for road purposes. A peculiar feature of these rocks is their position above the level of the surrounding bottom land, which makes access easy and provides for gravity handling.

The accompanying illustration (Pl. II, fig. 1) is reproduced from a photograph taken at Morton, in Renville County, on the line of the Minneapolis & St. Louis Railroad. The denuded rocks here shown cover an extent of half a mile or more, with a superelevation of from 50 to 75 feet, and are situated about one quarter of a mile southeast of the Morton depot. By placing a crusher at a convenient height above the service roads, all the material ever required can be fed down hill and the expense of preparing it reduced to a minimum. The same conditions exist at Granite Falls and numerous other points along the upper reaches of the river to the head—at the outlet of Big Stone Lake on the western boundary of the State.

The quartzite quarries at New Ulm, from which a large amount of road material has been shipped, are situated in Nicollet County, about 3 miles east of the city of New Ulm, and are extensively worked for macadam and concrete material. This stone was used for the surface of the University Avenue macadam in St. Paul and has been used also on streets in other cities both for the body and surface. Since it has, however, rather low cementing qualities, it is considered advisable to use in connection with it some stone having a higher cementing value. This quarry is now opened to a 30-foot face and has good facilities for handling the output. The accompanying illustrations (Pls. II, fig. 2, and III, fig. 1) are copied from photographs taken while the quarry was in operation and show the surface conditions to be the same as in the Morton exposures.

At Granite Falls the entire town site is built on granite and the immediate exposures continue unbroken for several miles up and down the valley. At this point, as at Montevideo, in Chippewa County, about 10 miles above, occur many isolated mounds from 20 to 40 feet in height, containing from fifty to several hundred thousand cubic yards of available stone above the level of a conveniently located crusher platform, and all this is easily accessible to railroads. Such a mound is shown in Plate III, figure 2.

Plate IV, figure 1, shows a 12-foot granite rock cut on the Chicago, Milwaukee & St. Paul Railway at the East Granite Falls depot.

The gray granite quarries of the Ortonville stone companies are located about 1½ miles down the valley from the city of Ortonville and are near the line of the Chicago, Milwaukee & St. Paul Railway.

As stated before, gravel of an excellent quality, containing varying proportions of lime and clay, and in nearly all cases a small quantity of iron, is to be found in the hills bounding the valley of the Minnesota River. In combination with the limestone, sandstones, and granites in the immediate vicinity of the river, this gravel affords splendid opportunities for the construction of macadam roads within economical hauling or shipping distance.

ST. CLOUD GRANITE QUARRIES.

In the vicinity of St. Cloud, on the Mississippi River, about 65 miles above the Falls of St. Anthony, are to be found extensive outcrops of gray and red granites, partially covering the country for an area 10 by 20 miles in extent. The writer is indebted to Mr. Samuel S. Chute, city engineer of St. Cloud, for the following report on the road material resources of that part of the State:

St. Cloud, the county seat of Stearns County, is situated in Stearns, Benton, and Sherburne Counties and is located in a large granite deposit, which extends to the north about 10 miles on both sides of the Mississippi, to the east 5 miles, to the west 14 miles, and southward from the city 2 miles.

The refuse stone from the larger number of quarries now in operation would make splendid macadam and the quarry owners are always glad to give the stone away, to have it removed. There are large hills of granite lying above the surface, of no value for monumental or cut stone, on account of the seams and cracks, but which would be easily handled for road building.

I am satisfied that there is now enough rock which could be easily and cheaply handled to build 1,500 miles of macadam road, and, as the owners open their quarries, this amount will increase. In Stearns County we have a large amount of most excellent soil for earth roads. Along the Mississippi we find sand, but also good gravel and black loam for covering. Getting away from the river, we find clay and gravel, both in abundance.

Mr. Chute's report indicates the same general conditions as exist along the Minnesota River above Mankato, especially in reference to the granite mounds which present such favorable conditions for economical handling.

The State reformatory is located near St. Cloud and during the past two years that institution has been utilizing some of the labor of the inmates in the construction of stone roads about the grounds. At Little Falls, on the Mississippi River about 28 miles above St. Cloud, are found beds of dark slate, varying from mica schist to argillyte, with extensive outcrops on each shore. Several other outcrops appear along the Swan River and in other adjacent localities.

Ledges of crystalline rocks appear in several localities in an area 20 miles square lying to the eastward of Little Falls and to the southward toward St. Cloud. Cretaceous beds occasionally occur with some slate showing at the different rapids. This slate has little value for road purposes except when used in connection with harder material, as it soon disintegrates under the action of the weather and travel.

RED QUARTZITE OF SOUTHWESTERN MINNESOTA.

The only known bedded rock in the extreme southwestern portion of the State is a red quartzite, probably the equivalent of the New York Potsdam sandstone, but Dr. C. A. White, of the Iowa survey, has designated it the Sioux quartzite, since it outcrops in the extreme northwestern corner of Iowa. Of this the largest exposures are in Cottonwood and Rock Counties, but the best known is at the famous "Pipestone Quarry" near the center of Pipestone County.

This outcrop of the Pipestone quartzite, as it is locally called, occurs near the city of Pipestone and extends 2 miles northwest, presenting several extremely favorable openings, many of which have been worked for building and concrete stone. It is also used quite extensively for curbs and paving. There are on the ground at the present time, near these workings, thousands of cubic yards of spawls of a suitable size for crushing and an unlimited supply can be obtained at a trifling cost for the quarrying. Many other outcrops of this stone appear to the southward toward Jasper and Luverne and furnish ample opportunities for obtaining excellent road materials at a moderate cost for quarrying. Plate IV, figure 2, shows the face of one of the Pipestone quarries from which much material has been taken for local use and for shipping. It is easily accessible and lies entirely above the adjoining surface. A spur track has been built into this quarry and every facility is offered for economical working.

THE TRAP ROCK OF EASTERN MINNESOTA.

The remarkable outcrops of trappean rocks forming the picturesque and grand Dalles of the St. Croix are some 30 miles south of the areas of these rocks on the St. Croix, Kettle, and Snake Rivers in Pine County. About a mile above Taylors Falls and close above St. Croix Falls trap rock occurs in the channel and on both sides of the river,

with an elevation of 50 feet in its highest portions. At Taylors Falls the St. Croix River enters its Upper Dalles, where, for three-fourths of a mile, it is walled on both sides by bold, often vertical, ragged cliffs, from 75 to 150 feet high, of tough, nearly black, massive trap. The origin of this formation, as in Pine County and in the Lake Superior region, appears to have been due to overflows of molten rock poured out from fissures of the earth's crust. This rock is extremely valuable as a wearing surface for macadam roads and efforts have been made to erect and operate a plant in the vicinity of Taylors Falls to supply the demand for that purpose and for concrete work. There are also quantities of the same rock obtainable near the mouth of the Kettle River, as well as in the vicinity of Carlton and Duluth. An 8-foot vein of trap rock appears in the granite quarries of Holes Bros. at St. Cloud. Plate V, figure 1, shows a railroad cut through the trap rock at Taylors Falls.

Plate V, figure 2, is from a photograph of a trap dike near Carlton in Carlton County.

SLATE.

Slate rocks are found quite extensively in the vicinity of Thomson, Cloquet, and Carlton in Carlton County and are known as the Thomson slates. They appear to have a somewhat finer grain than those at Little Falls on the Mississippi, as previously described, and have been somewhat extensively used on village streets and country roads. Several blocks in Carlton village, near Thomson, have been macadamized with slate rock locally quarried, and, though having been in use for about eight years, are still in good condition. Lately, however, it has been found advisable to put a gravel covering over them, and such a road seems to give general satisfaction when properly built and maintained. A number of years ago, in East Minneapolis, an experiment was tried of using this material, when ground fine, for surfacing, but it was not found to be very serviceable for heavy traffic, and the experiment was not repeated. Plate VI, figure 1, shows a slate cut in the village of Carlton, from which the material was taken for local use.

The eastern part of the State is further supplied with an excellent sandstone extending upstream along the Kettle River from near its mouth for a distance of 20 miles. The most important quarries of this stone are those of the Kettle River Quarries Co. at Sandstone, which have been operated for several years, and furnish a very superior product, extensively used throughout the State for bridge piers and abutments, macadam and concrete supplies, and for building purposes.

FIG. 1.—RAILROAD THROUGH GRANITE, NEAR THE CHICAGO, MILWAUKEE & ST. PAUL DEPOT, EAST GRANITE FALLS, MINN.

FIG. 2.—RED QUARTZITE QUARRIES AT PIPESTONE, MINN.

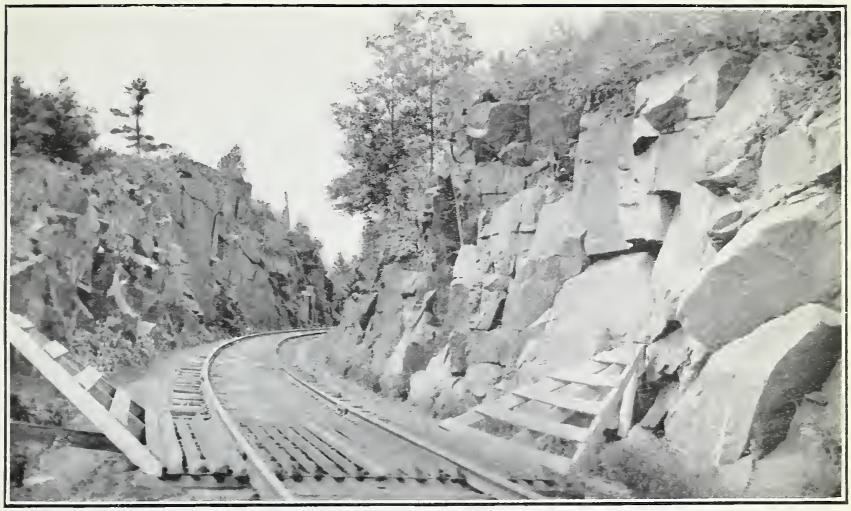

FIG. 1.—TRAP ROCK CUT AT TAYLORS FALLS, MINN.

FIG. 2.—TRAP DYKE AT CARLTON, MINN.

FIG. 1.—STREET CUT THROUGH SLATE ROCK, CARLTON, MINN.

FIG. 2.—EXPERIMENTAL GUMBO ROAD, NEAR CROOKSTON, MINN.

IRON-ORE ROADS.

The iron industry along the iron ranges in St. Louis County and extending westward into Itasca and Aitkin Counties has created a demand for inexpensive hard roads. This demand is supplied by the use of lean ore containing about 25 per cent of iron. Already about 150 miles of such roads have been built, and they furnish a very satisfactory solution of the road problem. Although that portion of the State is plentifully supplied with granite, trap, and slate, the cost of crushing and hauling has caused the more general use of the cheaper material, immense quantities of which are available at every mining center. These roads are generally constructed by depositing from 6 to 10 inches on the graded bed for a width of from 12 to 18 feet and allowing it to be compacted by travel. The results are very satisfactory, but the roads are necessarily dusty in dry weather and carry a slight coating of red mud when wet. A top dressing of coarse gravel would add materially to their value.

GRAVEL DEPOSITS.

In addition to the foregoing main sources, where inexhaustible supplies of good road-making material may be easily and cheaply obtained, with favorable shipping facilities in almost every case, the glacial drift has left numberless deposits of gravel scattered so conveniently over the State that only a small portion lies beyond the limit of economical haul, and such portions are easily served by the many lines of railroad now in operation.

GUMBO.

Along the Red River Valley, in the northwestern part of the State, as well as in a number of counties in the southern part, the soil consists of a heavy, dark clay, generally called gumbo, an excellent road material when dry and smooth, but extremely muddy and at times impassable during the wet seasons. To construct good roads with this material is a problem now being considered, and the solution of it lies along the well-known lines of perfect drainage and the elimination of vegetable material as far as possible. An experimental gumbo road was constructed near Crookston in Polk County in 1906, and, through careful maintenance, it has given great satisfaction. These roads must be provided with a well-rounded surface, so that water will flow off readily. Wheels are apt to skid on them while the surface is wet, and to prevent this the addition of a coating of sand or gravel is advisable when this can be obtained.

Along the eastern boundary of the ancient glacial Lake Agassiz, which formerly covered the river valley, lies a succession of sand and gravel beaches, distant from the Red River from 10 to 20 miles, and this source of supply must soon be drawn on for the construction of the Red River roads.

EXPERIMENTAL ROADS.

No. 1.—The following is a report on the experimental gumbo road, taken from the report of the State highway commission for 1906:

At a meeting of the highway commission, held May 1, 1906, the State engineer was authorized to expend the sum of $400 on an experimental road in the gumbo soil of the Red River Valley. The road selected was what is locally known as the State farm road, running north from the city limits of Crookston past the agricultural experiment station and lying on the line between section 24, township 150 north, range 47 west, and section 19, township 150 north, range 46 west.

The land was apparently level, having a slight slope not exceeding 5 feet per mile. From station 0 at the city limits to station 22, a distance of 2,200 feet, the road had been kept for some months in perfect condition by Prof. William Robertson, of the agricultural station, and the principal work done on that portion was on the ditches, to provide for perfect drainage. From station 22 north all sod was removed from the side of the road, and the ditches and the roadbed were well rounded, after which gravel, obtained from a pit on a haul about 1½ miles long, was placed on the road at the rate of 14 cubic yards per station of 100 feet, or 739 cubic yards per mile, and for a width of 14 feet.

This gravel was mixed with the loosened soil in different proportions, in order to determine the least quantity of gravel that might be used to advantage where such material is difficult to obtain. As was to be expected, where the maximum was used, the road was in the best condition, but it was found that for such soil the addition of even a small amount was a material benefit to the road. This experimental road has been in excellent condition every day since completion and has amply demonstrated the fact that with the use of gravel or sand good roads may be made throughout the Red River Valley, and even without the addition of any material to the native soil, but by a careful and continuous system of maintenance, such as had been applied by Prof. Robertson at a trifling cost, a vast improvement may be made in the roads of that portion of the State. The illustration (Pl. VI, fig. 2) is from a photograph taken about three months after the road was completed.

No. 2.—Along the eastern side of the Mississippi River, from near the vicinity of Brainerd in Crow Wing County to Anoka, comprising an irregular area about 80 miles in length by 20 or more in width in the counties of Crow Wing, Morrison, Benton, Mille Lacs, Isanti, and Anoka, the soil is a sandy loam, in many places without convenient clay deposits—conditions which make it difficult and somewhat expensive to construct good dry-weather roads. Frequent gravel deposits are being found, however, through this sandy portion, though at some distances from the places where required. Two

short stretches of experimental road have been constructed in this vicinity also.

Experimental road No. 2 was built on 1 mile of State Road No. 7, in Sherburne County, near Princeton. The surface is approximately level and the soil very sandy. For 60 feet in width it was cleared and plowed, and laid out in three strips of 20 feet each. The middle strip was turnpiked for road purposes and covered with a layer of rye straw 3 inches thick. The outside strips were planted with red and yellow clover mixed with rye, which had been cut and raked on the road bed. Owing to the lateness of planting and exceedingly dry weather during July and August, the clover did not grow well, but the experiment will be continued for several years with the expectation that the introduction of this vegetable matter into the sand will so change its character as to permit the use of ordinary road machinery with satisfactory results. Already with only a few months' experience the farmers who use this road speak very highly of it, and applications are coming in to the highway commission for a continuance of the plan.

No. 3.—One-quarter of a mile on State Road No. 1, in Isanti County, was laid out as experimental road No. 3. The surface is level and the soil very sandy. The surface was graded 30 feet in width, with the roadway 14 feet wide and covered with sawdust from 4 to 5 inches thick. The system of maintenance on this road, as on road No. 2, consists in occasionally raking the ruts and distributing the vegetable material uniformly over the traveled portion. It has not been in use long enough to judge the value of the experiment, but it appears to be a vast improvement over a sand road.

TESTS ON ROCK SAMPLES.

The following table, taken from the report of the Office of Public Roads dated January 1, 1911, shows the maximum and minimum results of tests on rock samples similar to the products of the Minnesota quarries:

TABLE 1.—*Results of tests of rock samples similar to products of Minnesota quarries.*

No. of samples.	Name.	Specific gravity.			Weight (pounds per cubic foot).			Water absorbed (pounds per cubic foot).		Per cent of wear.		Hardness.		Toughness.		Cementing value.	
		Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
183	Basalt	3.05	2.30	2.85	190	143	178	6.32	0.02	14.7	1.3	19.3	5.7	40	5	500+	2
198	Diabase	3.20	2.60	2.90	200	162	181	2.73	.03	6.3	1.1	19.4	12.3	54	4	500+	2
153	Dolomite	2.90	2.30	2.70	181	143	168	9.40	.07	18.6	1.2	18.4	1.8	27	3	179	9
40	Gabbro	3.65	2.75	2.95	228	172	184	.97	.04	5.9	1.3	18.8	13.3	23	8	115	6
196	Granite	3.00	2.00	2.65	187	125	165	2.77	.04	24.6	1.1	19.6	13.6	33	2	255	2
631	Limestone	2.85	2.00	2.65	178	125	165	13.22	.02	34.2	1.8	19.1	0.0	25	2	500+	10
87	Quartzite	3.15	2.35	2.60	196	147	162	2.95	.05	7.6	1.6	19.7	15.3	30	5	45	0
276	Sandstone	3.25	2.00	2.60	203	125	162	11.60	.02	41.7	1.0	19.5	0.0	60	2	500+	1
9	Shale	2.70	2.50	2.65	168	156	165	4.84	.50	16.2	3.2	17.7	13.9	12	3	367	28
53	Slag	3.90	2.00	3.25	243	125	203	4.40	.04	13.5	2.5	18.3	10.7	21	2	500+	1
54	Slate	3.35	2.60	2.75	209	162	172	2.10	.05	12.4	1.6	19.7	1.1	56	1	500+	1
27	Syenite	3.05	2.15	2.65	190	134	165	4.21	.08	14.4	1.6	19.2	17.3	34	8	375	10

Tests of rock samples from Minnesota, including sands and gravels, made by the Office of Public Roads, are given below:

TABLE 2.—*Road material from Minnesota tested in the Office of Public Roads.*

Serial No.	Locality.	Name.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
			Pounds.	*Pounds.*					
2426	Redwood Falls, Redwood County.	Granite	165	0.28	2.4	16.8	19.0	16	17
2427	do	Weathered granite	134	.....	15.2	26.0	.....	2	255
1241	St. Cloud, Sherburne County.	Granodiorite	168	.12	.....	.....	18.0	19	9
807	Duluth, St. Louis County	Olivine gabbro (trap).	172	.12	.....	.....	17.4	10	42
5301	do	Altered gabbro (trap).	172	.50	5.2	7.8	16.8	8	134
1170	Courtland, Nicollet County	Quartzite	165	.39	1.6	24.5	19.0	22	42
2340	do	do	165	.15	2.1	19.2	19.7	12	13
1010	Carlton, Carlton County	Slate	175	.67	6.0	6.7	11.2	5	43
2442	do	do	172	.53	2.8	14.3	12.7	10	75
2109	Mankato, Blue Earth County	Sandstone	.....	.....	.....	.....	.....	.....	50
2410	Pipestone, Pipestone County	Ferrugineous sandstone.	172	.40	4.6	8.8	14.5	16	11
2909	Minnesota City, Winona County.	Dolomite	168	1.74	5.0	8.0	13.3	5	42
3764	Mantorville, Dodge County	do	150	8.24	11.5	3.5	2.0	3	41
5320	Minneapolis, Hennepin County.	Washed sand	.....	.....	.....	.....	.....	.....	14
5323	do	Sand	.....	.....	.....	.....	.....	.....	52
5324	do	Sand gravel	.....	.....	.....	.....	.....	.....	169
5321	do	Washed gravel	.....	.....	2.0	20.0	.....	.....	23
5322	do	Gravel	.....	.....	.....	.....	.....	.....	40
2428	Redwood Falls, Redwood County.	do	.....	.....	.....	.....	.....	.....	148

It will be noted in comparing these tables that the products of the Minnesota quarries, as far as tested, compare very favorably with similar material from other sections of the country.

CONCLUSION.

That portion of the State lying along the eastern and northeastern boundaries is well supplied with sedimentary and crystalline rocks, as is the entire Minnesota River Valley. The extreme southwestern part is rich in quartzite and the granite outcrops near the central portion form a base of supply that can never be exhausted. Where suitable road stone is scarce, gravel may be found, though in some portions requiring a considerable haul. The roads of the Red River Valley and the southern part of the State will be built of clay and sand and those of the extremely sandy portions of sand tempered with vegetable matter or clay, and improved with gravel where possible. A large marshy area in the northern part remains yet to be developed, but with the completion of the drainage systems now under consideration and being constructed, and the opening of these lands to settlement, material will undoubtedly be discovered for road purposes in sufficient quantities to supply all demands.

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